AUTOMATIC AND THROTTLING GOVERNOR TESTS

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Automatic and Throttling Governor Tests.

C. Cresson Wistar Jr. 1904.

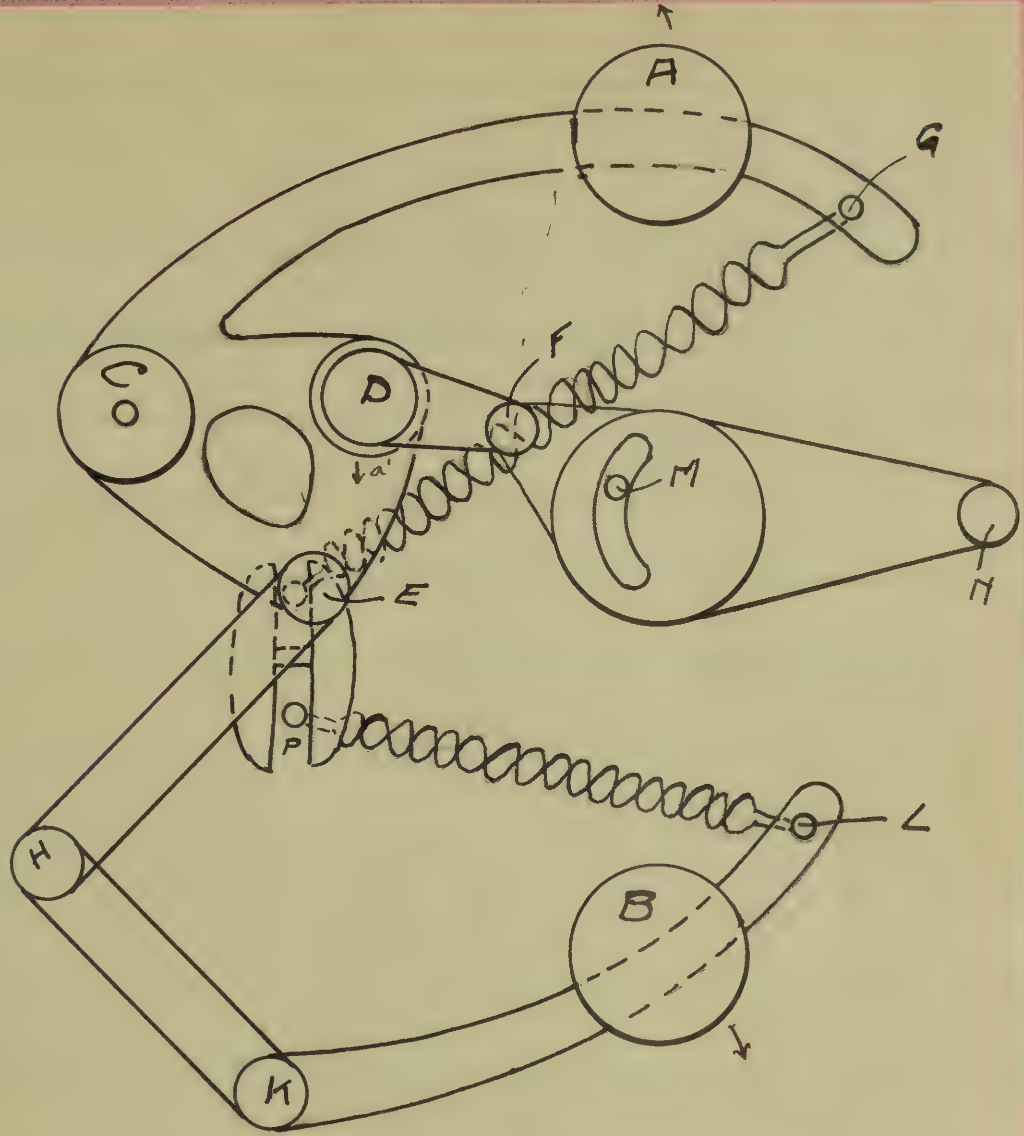
The object of these series of experiments is to determine which of the two governors is the more economical to use comparing them by the steam used per I.H.P hour or by the thermal efficiency of the engine, the compared runs to be taken as nearly under the same conditions as it was possible to obtain.

The throttle governor has a tendency to superheat the steam at light loads, this is quite an advantage in its favor as superheated steam gives a higher thermal efficiency than dry steam. There is another point however

in favor of the cut-off governor and that is it is safer, as it works entirely within the fly-wheel and does not require any belt or any gears, and is in fact much more compact, and can be handled more easily.

As to their relative economy we will compare that later and in detail.

The cut-off governor consists of two balls A & B which have a rectangular slot cut out of each of them in which fits the arms GC and KL. The piece GCDFE is all one piece pivoted at C on arm of fly-wheel. When the engine speeds up the balls



AUTOMATIC-GOVERNOR.

A and B have a tendency to move out as shown by small arrows this is caused by the centrifugal force of the balls and it is resisted by the tension in the springs GE and LP. The ends of the springs are attached to the ends of the arms CAG and KL and the other ends are fastened to a fixed point on the arm of fly wheel. When the centrifugal force is great enough to over come the tension in the springs the balls fly out and the piece GCDFE turns around (C) as a center. Both balls help the piece GCDFE to turn in the same


2
2
3
1.
4
5.

direction which is indicated by the small arrow a'. The movement of the triangular piece throws the eccentric accross the shaft increases the angle of advance and decreases the eccentricity thus making all the events of the cycle occur earlier and consequently making the engine slow down.

The principle of the throttle governor is quite different; the photograph shows it pretty clearly. The belt (1) connects the shaft of the fly-wheel over a small pulley mounted on a shaft of the governor which is in the steam pipe. The motion of this pulley is transmitted to a hollow vertical

spindle on which are mounted the two balls (2, 2.). The vertical spindle rotating at a high speed causes the balls to fly out by centrifugal force, this forces down a small vertical rod that passes through the vertical spindle, which is hollow, and on the other end of the rod is a valve. This valve closes partly when the rod is forced down and the steam is thus throttled off.

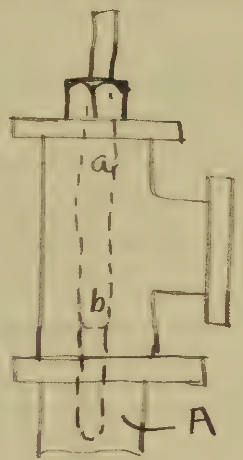
When the throttling governor was used the balls A & B of the fly-wheel governor were taken off after loosening the set screws and the engine was then entirely under the

control of the throttling governor.

The engine used was a 6 x 8 Weston High Speed Engine the rated horse power of which is fifteen.

The pipe line was equipped with two Calorimeters one above the throttling governor and the other below. The upper Calorimeter tested the quality of the steam as it came from the boiler and before it passed the valve of the throttling governor and the lower Calorimeter tested the quality of the steam after it was throttled. It turned out after it was too late to remedy it that the lower

calorimeter was not altogether reliable owing to the fact that one of the thermometer wells (a b) took up so much of the volume in the pipe (A) when the steam enters that the steam was super-heated in two cases viz - the third and fifth runs when the throttling governor was used and this was not shown by the calorimeter.



Method of Taking a Test.

The general arrangement of the apparatus is pretty clearly shown in the photograph with the exception of the condenser and the tank for weighing the exhaust steam; the latter is shown to the extreme left marked (4) and the former is back of the engine.

Having taken the zero reading of the brake and having gotten the engine to run smoothly the brake load at which the engine is to run is applied and all readings are taken as nearly as possible at regular intervals. These readings include, the weight

of the exhaust steam that flows into the tank marked (4) through a hose connected to the condenser. Revolutions were taken with a speed counter this method being more satisfactory than the continuous revolution counter in this particular case.

Some difficulty was found especially with the higher loads in keeping the brake constant while indicator cards were being taken and it was found by experience that the best method was to put the cards on the indicators, connect up the reducing motion and open the cocks of the indicators then adjust

the ropes of the brake until the scales just balanced keeping the load constant, then take the two cards as near the same time as possible while the brake was just balancing.

Readings were taken on the two thermometers, on each calorimeter, which thermometers were interchanged at intervals to see if their readings corresponded, readings were also taken of the upper and lower pressure gauges.

At first on a preliminary run the exhaust steam was allowed to run into a bucket and when it was filled the water was thrown into the

weighing tank and the hose from the condenser placed in another bucket. While this method lessened the back pressure in the condenser it required too much constant watching to prevent the buckets from over-flowing and as it was of more importance to keep the brake constant this method was abandoned and the condensed steam was allowed to run directly from the condenser to the weighing tank.

Various methods were tried to make the brake remain constant without so much constant watching and

among others, soap was rubbed over the face of the brake fly-wheel but the fly-wheel got so hot (in spite of the cooling water that ran in the rim) that the soap melted, wetting the ropes and causing them to tighten so much that the engine had to be stopped.

— The Instruments Used. —

Crosby Indicators #7051 and 7050
Pressure Gauges 189437 and 189438.
4 Thermometers
Two Scales
1 Speed Counter.

The instruments were

calibrated before and after the tests were made. The pressure gauges were calibrated by the Crosby Tester and gauge # 189437 did not vary much in the two calibrations, but with gauge # 189438 the second calibration varied so much from the first that the only conclusion to draw was that the hand of the gauge had been reset the latter calibration only was used as the gauge was not used until the last seven runs. The calibration curves of the two gauges are shown.

The indicator springs were tested in the regular manner.

The spring scales were rated at 50 pounds per inch: before the runs the average value of the scale of spring #1 was 49.64 pounds per inch, and of spring #2 was 49.75 pounds per inch: after the tests the scale of spring #1 was 48.5 pounds per inch and #2 was 48.05 pounds per inch. For the first half of the series of runs the first calibration was used and for the second half the second calibration was used.

Method of Working up Results.

In working up the results having calibrated the instruments the engine and brake constants were first found.

The dimensions of the engine were found to be —

Diameter of Cylinder = 6"
Stroke = 8"
Diameter of Piston Rod = $1\frac{1}{8}$"

The engine Constant for the head end for first half of the series of runs is —

$$\text{Constant} = \frac{l \times a \times s}{33000 \times 12}$$

$$= \frac{8 \times .7854 \times 36 \times 49.64}{33000 \times 12}$$

$$= .0283$$

The (l) in the above formula equals the length of stroke; (a) equals the area of piston at head end, and (S) equals the value of the spring scale for the head end.

The horse power for the head end equals the constant × mean ordinate × number of revolutions per minute. In a similar way the constant for the crank end is found the only difference being the area of the piston rod is subtracted from the area of the piston and the spring scale is different.

$$\text{Constant (crank end)} = \frac{8 \times .7854 \times (36 - 1.27) \times 49.75}{33000 \times 12}$$

$$= .0274$$

The brake arm was two feet eleven inches long therefore the brake constant equals

$$C = \frac{2\pi r}{33000} = \frac{6.28 \times 2.92}{33000}$$

$$= .000557$$

The brake horse power is found by multiplying the constant by the net load on the brake and also by the R.P.M.

Of course the principal thing to find in this series of tests is the steam used per I.H.P. hour comparing the runs taken under similiar conditions. But to further test the engine with the two governors both the

mechanical and thermal efficiencies were found. In order to find the latter it was necessary to determine the value of x (which is the quality of steam in percent) This was done with the lower calorimeter. This value of x is determined by equating the total quantity of heat on each side of the diaphram of the calorimeter and neglecting the heat lost by radiation which is a small quantity the heat balance is ——

$$q + x r = q_1 + r_1 + .48(T_{sup} - T_{sat})$$

In which q is the quantity

of heat that is in the water when it is about to boil and r is the latent heat of steam. These two expressions are found in Peabody's Saturated Steam Tables at temperature obtained from the upper thermometer; q_1 and r_1 are the values corresponding with atmospheric pressure. (T_{sup}) is the reading of the lower thermometer on the Calorimeter and it is generally superheated.

The thermal efficiency (ϵ_1) is now obtained from the following formula if the steam is not superheated before it reaches the lower Calorimeter.

$$\epsilon_1 = \frac{\frac{33000}{778}}{(q + xr - q_0)\frac{W}{60}}$$

In which again q and r are the values from the reading of the upper thermometer of the Calorimeter and q_0 is obtained from the temperature of the feed. If the Condensed steam could have been used as feed water then the q_0 could have been taken from the temperature of the exhaust steam. The (W) is the weight ~~per minute~~ per I.H.P hour. If the steam is superheated the formula is some-what different, in this case it is —

$$\epsilon_1 = \frac{\frac{33000}{778}}{\left[q + r + .48(T_{sup} - T_{sat}) - q_0\right]\frac{W}{60}}$$

Here the $(q + r)$ or λ are

found in Peabody's Saturated Steam Tables for the corrected gauge pressure of the lower calorimeter and the temperature of the saturated steam corresponding with this corrected pressure reading is subtracted from the upper temperature of the lower calorimeter, this difference is then multiplied by the specific heat of superheated steam which is (.48). The q_0 and the W are the same as in the other formula.

Sample Calculation.

Taking for example the calculation for the second set of readings under the third run of the fly-wheel governor.

The average R.P.M. for the run was 333. Multiplying the two constants before found by this we get two new constants for this run only one for the head end and the other for the crank end

.0283 × 333 = 9.44 for Head end
.0274 × 333 = 9.13 " Crank end.

Having found these two constants we can get the indicated

horse power by simply multiplying these constants by the mean ordinate.

I. H. P (Head end) = 9.44 × .312 = 2.95
I. H. P (Crank end) = 9.13 × .266 = 2.43
Total I. H. P = 5.38

The .312 and .266 are the mean ordinates taken from the cards.

The Brake Horse Power = B.H.P

B.H.P = .000557 × 333 × 20
= 3.71

In finding the B.H.P the .000557 is the brake constant before found, the 333 is the R.P.M. and the 20 is the load on the brake. The B.H.P

remains constant during the run.

Mechanical efficiency = $\frac{B.H.P}{I.H.P}$ = e

$$e = \frac{3.71}{5.38} = 69.1\%$$

The total steam used per hour = 398.# Hence the steam used per I.H.P hour

$$= \frac{398}{5.38} = 74.1\#$$

We next find the value of the quality of steam from the formula found above and we get

$$360.5 + x \times 882.1 = 1146 + 21 \times .48$$

from which $x = 97\%$

Our next step is to find the

thermal efficiency which equals

$$\epsilon_1 = \frac{\frac{33000}{778} \times 60}{(299.4 + .97 \times 882.9 - 116.3)\,74.1}$$

$$= 3.29\ \%$$

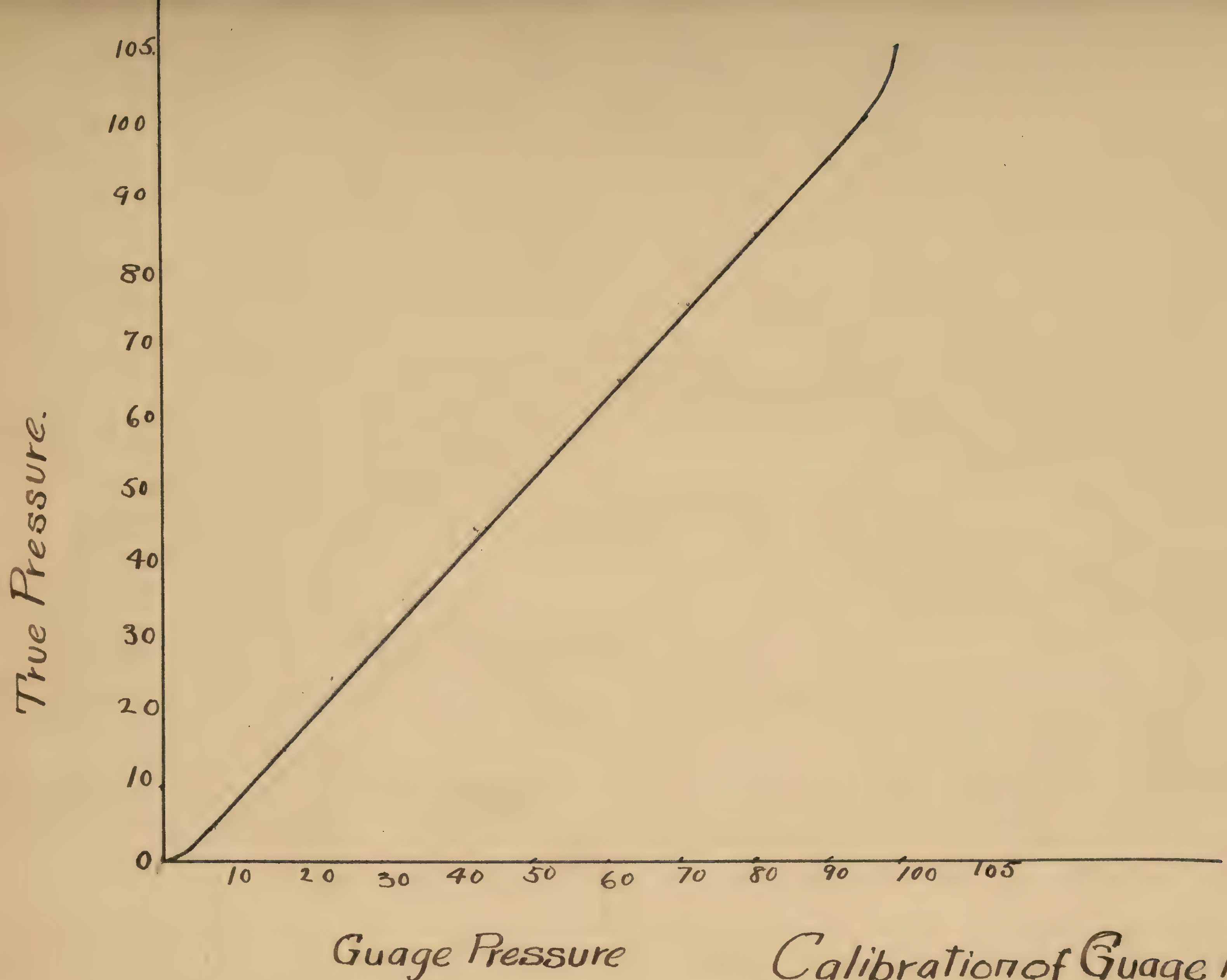
Conclusions.

The conclusions can best be drawn from the table given and also from the two curves illustrating the steam used per I.H.P hour. The throttle governor uses more steam per I.H.P. hour in each case ranging from eleven to twenty five pounds of steam more per I.H.P hour than the Automatic governor. This can be explained to a certain extent by stating that the cut-off, when the throttle governor was used, was very late not occurring until about eighty-three per cent of the stroke, this

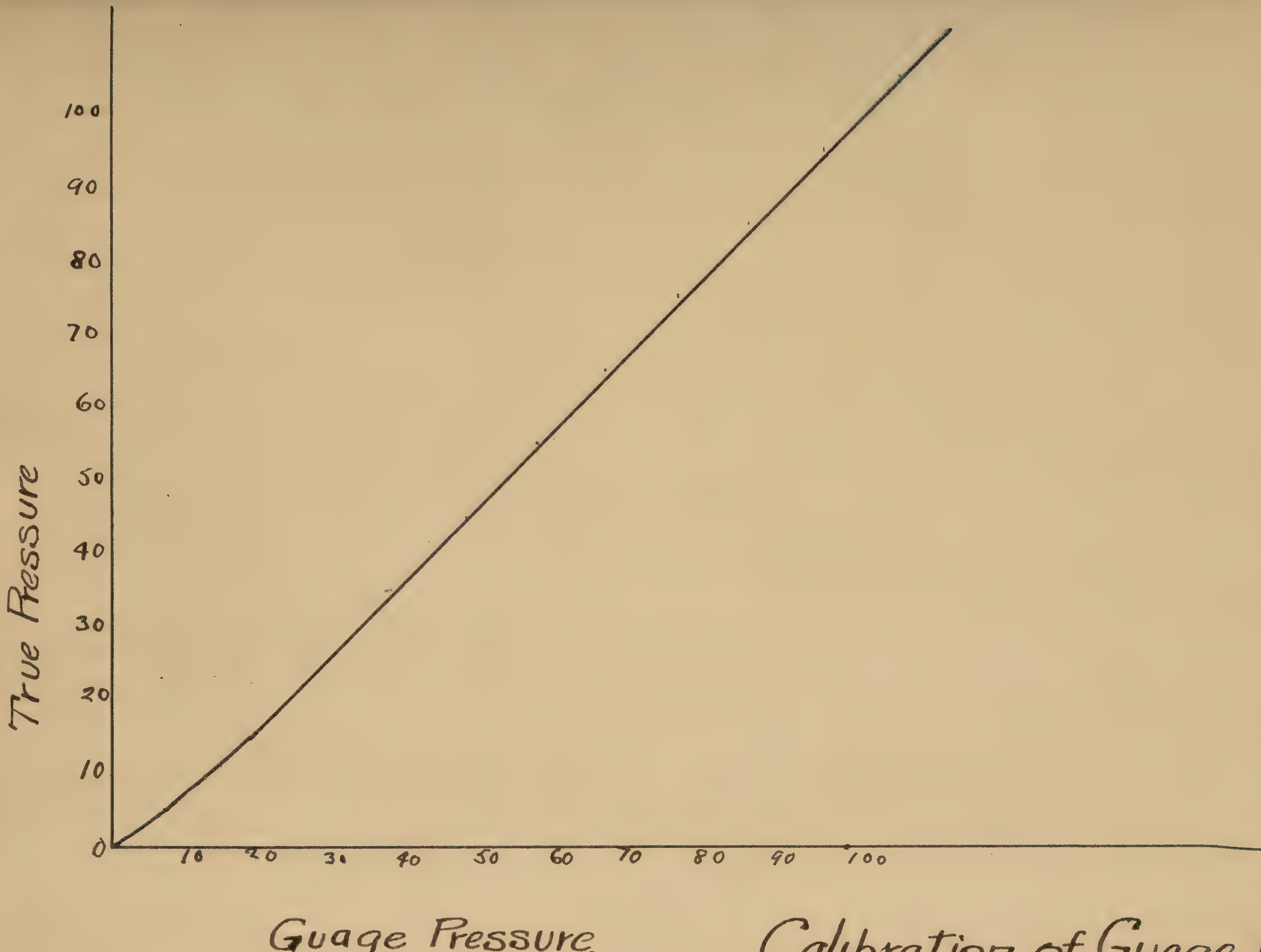
can be seen very readily from the sample cards in back of thesis. If the fly-wheel governor could have been blocked up so as to give a cut-off of say fifty percent the steam ~~the steam~~ consumption of the throttle governor would have been much reduced. The thermal efficiencies show practically the same result as the steam consumption.

Run*	Governor	I.H.P.	Steam per I.H.P.h.	Mech.eff.	Thermal eff.	Brake
1	Aumat.	2.933	103.9*	64.6	2.56%	9.75
1	Throt.	2.797	114.25	60.49	1.97	9
2	Aumat.	5.31	74.84	69.8	3.33	20
2	Throt	5.61	92	69	2.60	20
3	Aumat	7.35	58.2	75.7	4.30	30
3	Throt.	6.451	78.97	87.7	3.33	30
4	Aumat	9.75	50.85	76.45	5.11	40
4	Throt.	8.181	62.37	92.4	3.88	40
5	Aumat	10.18	45.74	91.6	5.15	50
5	Throt.	10.13	60.95	92.4	3.06	50
6	Aumat	11.775	45.8	96.5	5.40	60
6	Throt.	11.86	58.3	94.2	4.585	60
7	Aumat.	13.73	43.47	96.98	5.84	70
7	Throt.	13.114	55.06	98.75	4.849	70

CURVES.

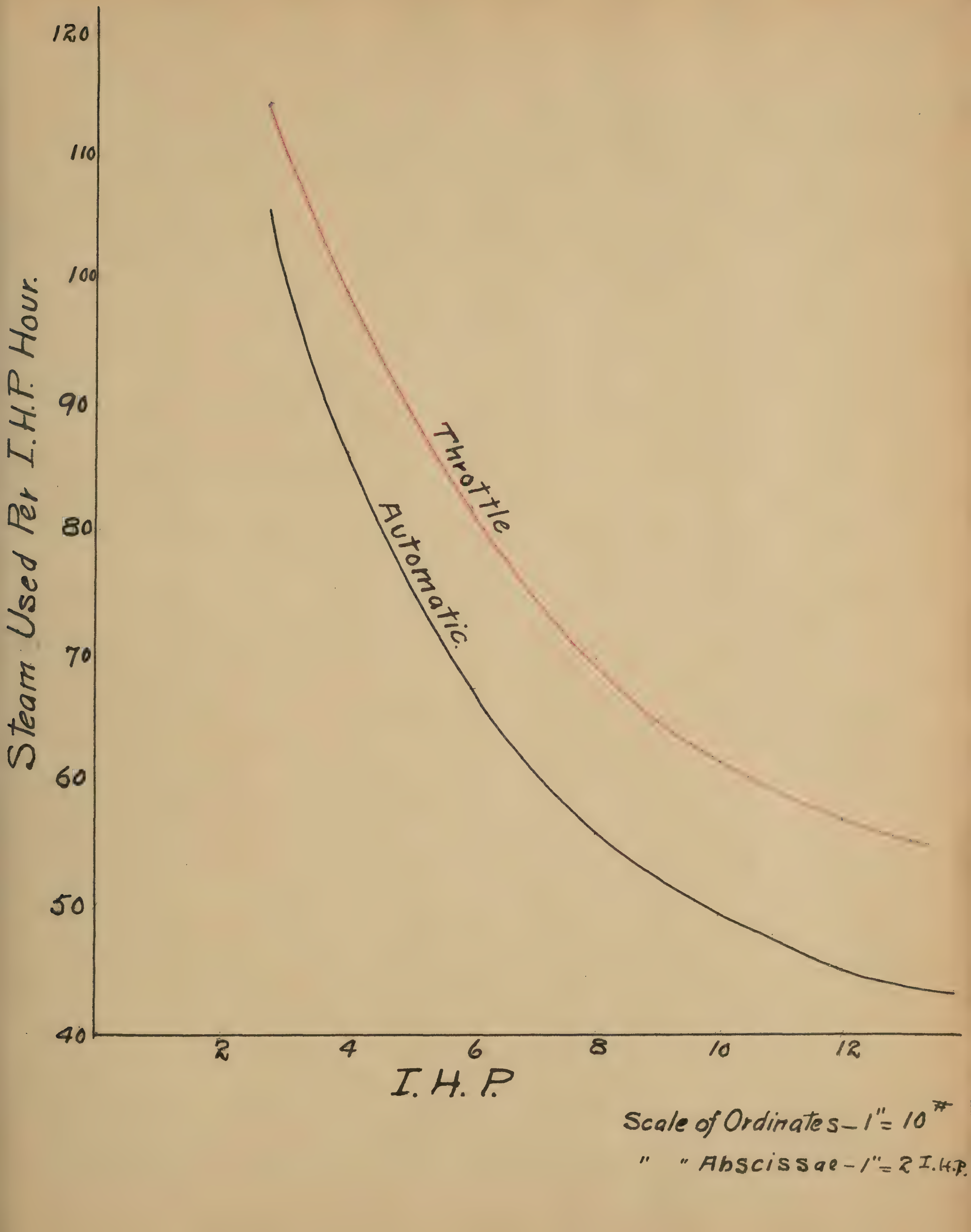


Calibration of Guage 189438.



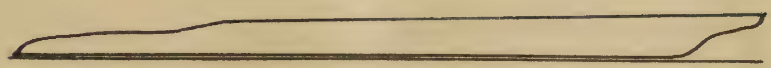
Calibration of Guage 189437.

Scale of ordinates — 1" = 20#
" " abscissae - 1" = 20#



Steam Used Per I.H.P. Hour.
120
110
100
90
80
70
60
50
40
2
4
6
8
10
12
I. H. P.
Throttle
Automatic.
Scale of Ordinates – 1" = 10#
" " Abscissae – 1" = 2 I.H.P.

SAMPLE-CARDS.

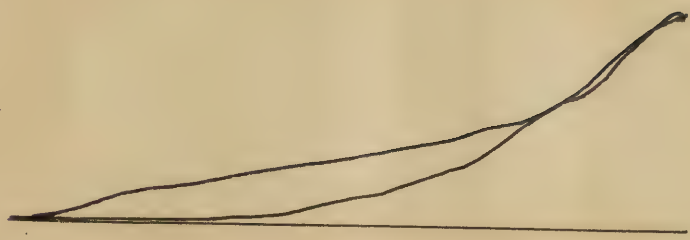


Crank - End.

Throttle Governor.

Net Brake Load = 9#

Head End.

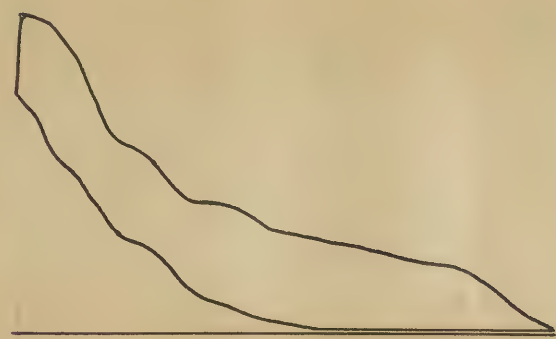


Crank End.

Automatic Governor

Net Brake Load = 9.75#

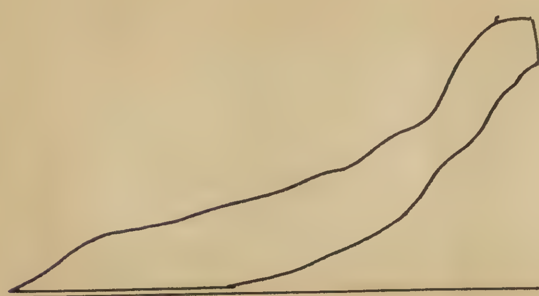
Head End.



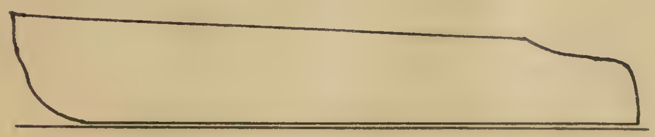
Head End.

Automatic Governor.

Net Brake Load = 40



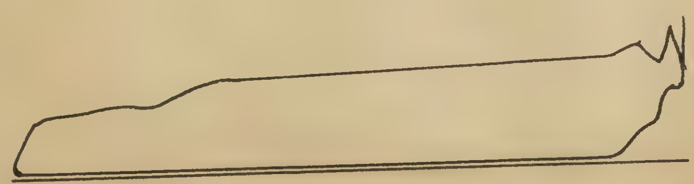
Crank End.



Head End.

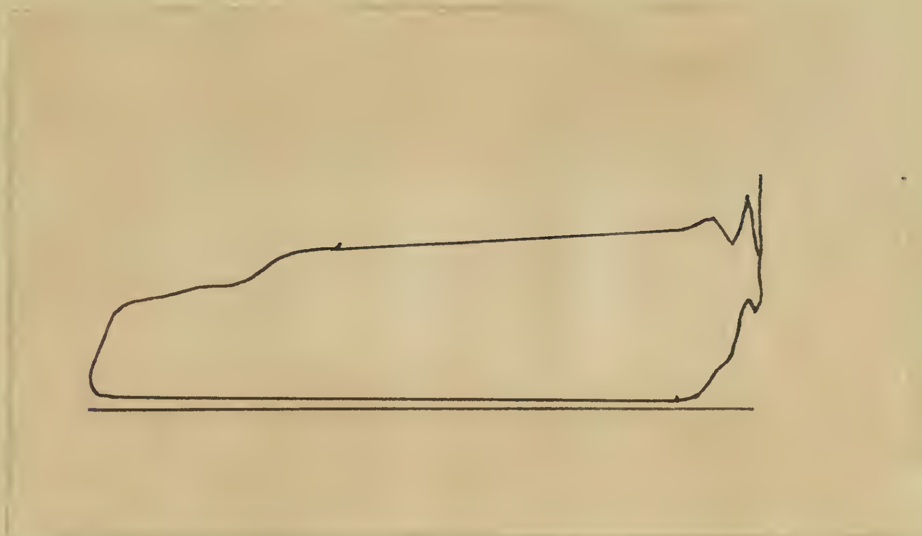
Throttle Governor.

Net Brake Load = 40

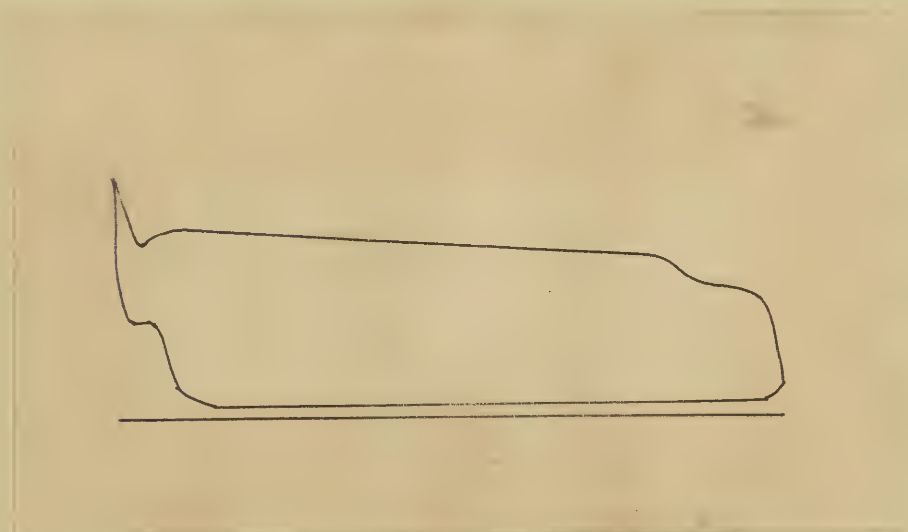


Crank End

Crank End.

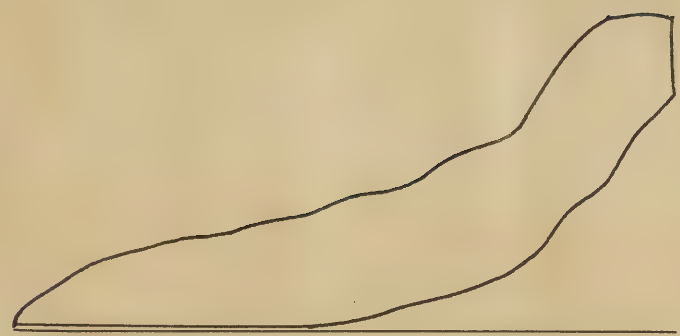


Throttle
Net Brake Load = 70 #



Head End.

Crank End.



Automatic Governor.

Net Load on Brake = 70

Head End -

ST